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Development of Effective Approach for Dewatering Microalgae

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ABSTRACT

The focus of this study lies on the effect of centrifugation on algal cell structure. Centrifuge experiments were conducted on *Scenedesmus quadricauda* and *Chlorella vulgaris* at different centrifugal speeds between 1000 to 4000 rotation per minute and varying time between 5 to 30 minutes. Dewatering efficiency and microalgae cell disruption were evaluated. To assess the effect of centrifugation on microalgae cell wall, cell images before and after centrifugation were compared. Cell images were captured using microscope camera with image-focus 4 software. Experimental results indicated that centrifugation technique is an effective approach for dewatering microalgae under specific conditions 4000 rotation per minute for 10 minutes. *Scenedesmus quadricauda* and *Chlorella vulgaris* respectively showed highest biomass recovery because they respectively resulted in 82% and 91% dewatering efficiency. This study provides information on specific impact of centrifugation on *Scenedesmus quadricauda* and *Chlorella vulgaris* for the first time, therefore providing specific option for microalgae dewatering technique in the energy industry.

Keywords: Microalgae, Cultivation, Harvesting, Dewatering, Centrifugation, Biomass.

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1. INTRODUCTION

Microalgae are considered as good material source to produce biodiesel, which has the potential to completely replace fossil diesel in the future [1] . The combination of CO_2 fixation, biogas production, wastewater treatment, as well as the production of high value end products such as human and animal and feed, pharmaceuticals, cosmetics, providing a clean, safe, reliable and secure energy supply around the globe makes microalgae a very promising for use in industrial processes [2], [3], [4], [5]. However, the major drawback for industries is the harvesting and dewatering. The challenges of dewatering centre around the microscopic nature of the algae around 5-30 μm in diameter, and due to the dilute nature of microalgal cultures at 0.3-0.5 g L^{-1} dry biomass [6]. Moreover, the microalgae dewatering process cost account for about 20-30% of the entire production processes cost [7]. To overcome this problem, different dewatering strategies have attracted considerable attention.

Common microalgae harvesting and dewatering operations are accomplished through centrifugation, freeze drying, bioflocculation, flotation, flocculation, sedimentation, filtration, or combination of above methods [8]. Currently there is no superior or universal method suited to all algal species of dewatering microalgae. On the one hand, a method may result in a greater algal biomass on the other hand, may have drawbacks such as high capital cost, high energy consumption, risk of contamination, and cell damage, these drawbacks are problematic. On the other hand, some methods may be time consuming. Among these process, centrifugation is the most common method (over 95% algal biomass could be obtained) and is widely used for microalgal cells harvesting in lab-scale or pilot-scale microalgae cultivation systems. However, the issue of cell damage impedes its further application at a large scale [9].

A careful review of the available literatures revealed that in spite of centrifugation study and the conclusion generally reported that this technique damage microalgae cell wall, none of these literatures assessed the level of damage on microalgal cell for centrifugation technique. Thus, in the present study, the effect of centrifugation on fresh water microalgal *Scenedesmus quadricauda* and *Chlorella vulgaris* is investigated as to assess the level of cell damage and to enhance this technique.

2. CENTRIFUGATION

Centrifugation involves principles of sedimentation, where the acceleration at centripetal force causes denser substances to separate out along the radial direction at the bottom of the tube. Centrifuge involves fast rotating machinery, at high speeds. Further, it consists of interlocks necessary so that the centrifuge cannot be opened until the bowl has stopped rotating. In centrifugation it is important to differentiate between the speed of centrifugation rotations per minute (RPM) and the relative centrifugal force (RCF or G) since these are often confused [10]. The centrifugation force is generated by a centrifuge can easily be calculated from the Equation 1.

$$RCF = 11.18\ x\ R\ x\ (\frac{RPM}{1000})^2 \quad (1)$$

Where R is the distance from the centre of rotation in centimetres that is, the centrifugal force increases as the particle move down the centrifuge tube. As a general rule the greater the centrifugal the shorter the separation time.

3. MATERIALS AND METHODS

Scenedesmus quadricauda and *Chlorella vulgaris* (UTEX 2714 and 1589) were obtained from University of Texas at Austin. The algal were cultivated in a sterilized BG 11 medium with the following composition $NaNO_3$Mm; K_2HPO_4 0.23Mm; $MgSO_4.7H_20$ 0.3Mm; $CaCl_2.H_20$ 0.24Mm$Na_2EDTA.2H_20$ 0.0027Mm; Na_2CO_3 0.19Mm. The cultures were cultivated in 2L PBR which contain 1600 ml of medium at pH 7.0 and at 25 ^oC at light intensity of 200-500 µmol photon $m^{-2}s^{-1}$.

Medium size centrifuge (Centaur 2 MSE PA3985) was used in this study. The centrifuge consists of four 50 ml swinging bucket rotor (Figure 1).

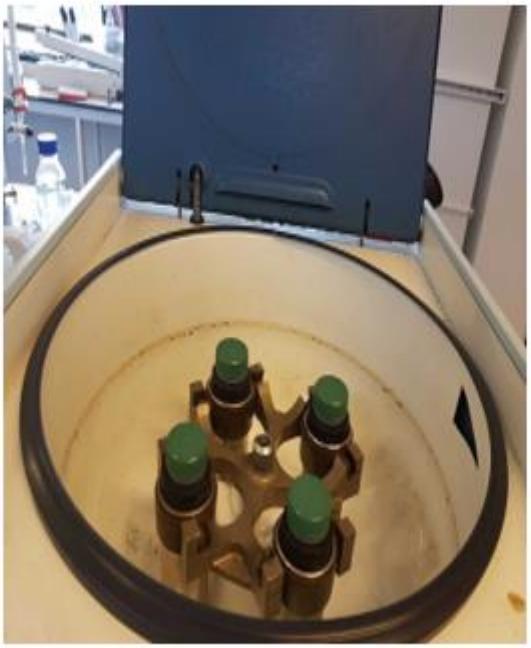

Figure 1. Centrifuge

Cell images were acquired using Novex B-range microscope (Holland) images were captured using Euromex microscope at 40x camera with ImageFocus 4 software. The force exerted on the algal sample in the centrifuge during experimentation was calculated using Equation 1. This is important as this gives better understanding of the mathematical process of the lab scale with an anticipation that this will help scaling up from lab to pilot or commercial scale. Further, it is essential to determine the G-force this is represented by Equation 2.

$$G.force = \frac{rw^2}{g} \quad (2)$$

Where r is the radius from the centre of the rotor in (cm), w is the number of revolution, g is the relative centrifugal force (RCF).

4. RESULTS

The experimental parameters, rotation per minute (rpm) and time were checked in two levels respectively: constant Rpm and varying Rpm then constant time and varying time. Rpm varies between 1000-4000 while time varies between 5-30 minutes. All experiments were run at least

in duplicate. The total weight of dried algal sample was calculated. Furthermore, the dewatering efficiency was calculated by the following equation:

$$E = \frac{Ci - Cf}{Ci} x\ 100 \quad (3)$$

Where E is the centrifugation efficiency in %, C_i is the weight of the algal samples prior to centrifugation process, and C_f is the weight of bottle and sample after centrifugation respectively expressed in gram (g) units. Parameters and results are shown in Tables 1 and 2.

Table 1. *Scenedesmus quadricauda* centrifugation responses

Experiment	Time (mins)	Rotation (RPM)	Dewatering efficiency (%)
1	5	4000	79
2	10	4000	82
3	15	4000	81
4	20	4000	81
5	25	4000	81
6	30	4000	81
Constant Time			
7	15	4000	81
8	15	3500	81
9	15	3000	81
10	15	2500	81
11	15	2000	81
12	15	1000	81

Table 2. *Chlorella vulgaris* centrifugation responses

Experiment	Time (mins)	Rotation (RPM)	Dewatering efficiency (%)
1	5	4000	82
2	10	4000	91
3	15	4000	83
4	20	4000	82
5	25	4000	82
6	30	4000	82
Constant Time			
7	15	4000	82
8	15	3500	82
9	15	3000	82
10	15	2500	82
11	15	2000	82
12	15	1000	82

The force exerted on the algal sample in the centrifuge force (RCF) and G-force during experimentation was calculated. Centrifugal force calculations predict strong correlations in terms of scalability. Since the greater the centrifugal force the shorter the separation time this is seen from the RCF result that 4000 RPM gave the greatest RCF as 167.7 (Table 3). These

parameters are important as it relates to a better understanding of the mathematical process with an anticipation that this will help scaling up from lab to pilot or commercial scale.

Table 3. RCF and G-Force Results

Experiment	RPM	RCF	G-Force
1	4000	167.7	2.828
2	3500	156.7	2.831
3	3000	145.06	2.831
4	2500	132.4	2.832
5	2000	118.22	2.837
6	1500	125.78	2.309
7	1000	83.85	1.885

To assess the effect of centrifugation on microalgae cell wall, prior dewatering, each microalgal cells were captured. After centrifugation all algal cells were compared to assess the difference between the control cell image (Figure 2) and cells after centrifugation. Consequently, there was no significant difference in cell wall at 4000 RPM for 10 minutes (Figure 3). Similarly, the same observation was seen in *Chlorella vulgaris*.

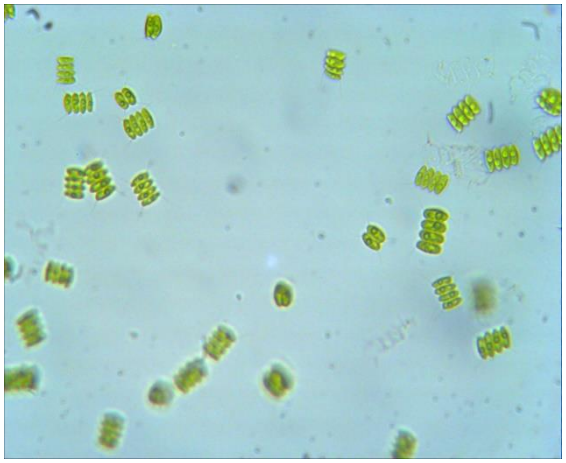

Figure 2. *Scenedesmus quadricauda* control image

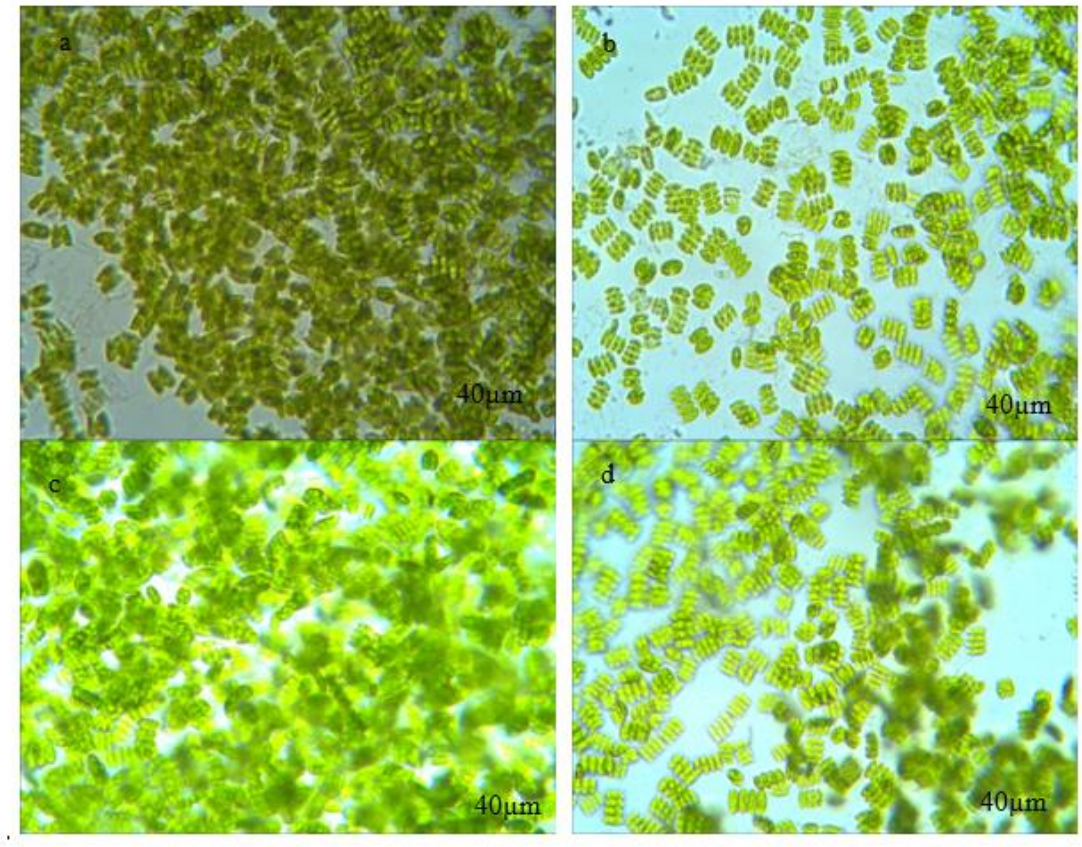

Figure 3. Constant rpm (4000) and varying time (a) 5 (b) 10 (c) 15 (d) 20

5. Conclusions

On the basis of the observations from these extensive experiments, it is greatly possible to centrifuge microalgae in practice without significant damage on cell wall as this is dependent on the operational parameters. Centrifugation technique showed highest dewatering efficiency of 81% and 91% respectively for *Scenedesmus quadricauda* and *Chlorella vulgaris*. The best parameters with respect to RPM and time are 4000 and 10 minutes respectively, where the greater the centrifugal force the shorter the separation time. From this experimentation consequently, different combinations of techniques would further be required to enhance the economics and competitiveness of microalgae dewatering technique.

6. References

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